

A New Species of the Genus *Attheyella* (Copepoda: Harpacticoida: Canthocamptidae) from Gosu Cave in Korea

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ABSTRACT—A new species, *Attheyella namkungi* sp. nov., is described from Gosu cave at Danyang, Chungcheongbuk-do, South Korea. This species bears a superficial resemblance to *A. coreana* Miura, 1969 in having a 2-segmented mandibular palp with only four smooth apical setae, and in the armature formulae of the antennary exopod and thoracic legs. However the new species is clearly distinguishable by the non-sexually dimorphic caudal rami, two long plumose setae and a short seta on leg 6, and the absence of the setular row at the inner lateral margin of each caudal ramus. The new species is characterized from other congeners by having two adjacent inner spines on female leg 3 endopod-2, the caudal ramus twice as long as its width, absence of a barbed apophysis on male leg 3 endopod-2, and the seta number of legs 5 and 6. A key to the Korean species of the genus *Attheyella* is provided.

Key words: *Attheyella namkungi* sp. nov., Harpacticoida, cave fauna, Copepoda, Korea

INTRODUCTION

Copepods are common components of ground-water faunas, and more than 900 species/subspecies are known from continental ground waters (Galassi, 2001). Canthocamptid harpacticoids, among them the genus *Attheyella* Brady, 1880, are well known as dwellers in small freshwater accumulations, and even in wet tropical soil and subterranean water (Reid, 1984). So far the genus *Attheyella* consists of 88 valid species (Boxshall and Halsey, 2004) within six subgenera: *Attheyella* Brady, 1880; *Mrazekiella* Chappuis, 1929; *Canthosella* Chappuis, 1931; *Chappuisiella* Brehm, 1926; *Rylowiella* Borutzky, 1932; *Delachauxiella* Brehm, 1926 (Dussart and Defaye, 1990; Galassi, 2001; Pesce, 2005).

Reports on the genus *Attheyella* in Korea are limited to only a few works following Miura's record (1969) of *A. coreana* Miura, 1969 from Daeya and three other caves. Chang and Kim (1992) described *A. paucisetosa* Chang and Kim, 1992 from a spring on Mt. Hambak in east-central Korea and *A. byblis* Chang and Kim, 1992 from a spring on Mt.

Halla, Cheju Island. Chang (1993) described *A. tetraspinoza* Chang, 1993 from a spring on Mt. Nochu and reported additional localities for *A. coreana*, *A. paucisetosa*, and *A. byblis*. Finally, Chang and Lee (2003) reported *A. crassa*, *A. nakaii*, and *A. orientalis* and presented a key to the seven *Attheyella* species in Korea.

During a survey of the cave fauna in Korea, a new species of *Attheyella* was collected from Gosu cave at Danyang-gun, Chungcheongbuk-do. The present study provides an illustrated description of the new species and a key to the species of *Attheyella* in Korea.

MATERIALS AND METHODS

Gosu cave, a busy tourist locality, is situated at 36°59'(12"-50")N, 128°(22'-24')E, within the Danyang limestone cave area, Chungcheongbuk-do, South Korea. The cave has several natural springs and artificial streams. The average water temperature is 13.4°C, the pH 8.2, and the salinity 0.15‰.

The specimens examined were collected by plankton net in a stream within Gosu cave from 7 August 2003 to 11 September 2004. Specimens were fixed and preserved with 70% ethanol. Before dissection, the habitus was drawn and body length measurements were made from whole specimens temporarily mounted in lactophenol. Specimens were dissected in lactophenol, and the parts were individually mounted in lactophenol under the cover slips that were subsequently sealed with Glyceel or transparent nail var-

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nish. An Olympus BX51 microscope fitted with a drawing tube was used to study details at 1000× magnification with oil immersion and to prepare figures. Some specimens were prepared by dehydration through alcohol series, critical-point dried, sputter-coated with gold, and examined with a scanning electron microscope (Hitachi S2380N).

The descriptive terminology follows that of Huys *et al.* (1996) and Fahrenbach (1962). Abbreviations used in the text are: A1, antennule; A2, antenna; ae, aesthetasc; exp, exopod; enp, endopod; exp(enp)-1(2, 3), the proximal(middle, distal) segment of a ramus; cp, copulation pore; ms, modified seta; iw, integumental window; omg, opening of medial gland; ooa, opening of oviduct into antrum; rcd, rim of copulatory depression; sr, seminal receptacle. Scale bars in figures are indicated in µm.

DESCRIPTION

Family Canthocamptidae Sars, 1906

Genus *Attheyella* Brady, 1880

Attheyella namkungi sp. nov. (Figs. 1–10)

Type locality. A stream in Gosu cave at Danyang-gun, Chungcheongbuk-do, South Korea.

Etymology. The specific name *namkungi* is named after Namkung Jun, a pioneer of the study of Korean subterranean animals.

Material. Holotype: 1♀ (NHM 2005-289), collected 07 Aug. 2003, dissected on 10 slides. Paratypes: 1♂ (NHM 2005-290), in 70% alcohol, collected 7 Aug. 2003. Other paratypes: 5♀ 5♂ (NHM 2005-291-300), 7 Aug. 2003; 3♀ 1♂, 11 Oct. 2003; 16♀ 5♂, 8 Dec. 2003; 17♀ 3♂, 19 Dec. 2003; 4♀ 3♂, 18 Feb. 2004; 101♀ 3♂, 11 Sept. 2004 (all in 70% alcohol); and 2♀ 1♂ from same locality as holotype, on SEM stub. All specimens are from a stream in Gosu cave at Danyang-gun, Chungcheongbuk-do, South Korea, and were collected by Y.G. Choi and B.W. Kim. The holotype and some of the paratype specimens were deposited in the Natural History Museum, London. The other paratypes were deposited in the central collection of the Department of Life Science, Hanyang University, Korea.

Female (Holotype)

Total body length=1088 µm, measured from anterior margin of rostrum to posterior margin of caudal rami. Largest width=310 µm, measured at posterior margin of cephalic shield. Urosome gradually tapering posteriorly (Fig. 1A). All somites except anal strongly serrated on hind edge of dorsal surface (Figs. 1A–B).

Prosoma (Figs. 1A–B) comprising cephalothorax, incorporating first pedigerous somite, and 3 free pedigerous somites. Cephalothorax with oval integumental window (Figs. 1A–B). Rostrum small, protruding, indistinctly separated from cephalosome, with pore in the posterior part and pair of sensilla near anterior margin (Fig. 1A). Pedigerous somites covered with minute spinules on both posterolateral margins. Body slightly constricted between somites.

Urosome (Figs. 1A–B) 5-segmented, comprising leg-bearing somite 5, genital double-somite (representing fused genital and first abdominal somites), and 3 free abdominal

somites. Ventral surface smooth and ventral hind margin with large spinules laterally and medially. Hyaline frills of urosomites not distinct.

Genital double-somite breadth about 1.5 times its length. Genital field as in Fig. 3G. Ellipse-type copulatory pore located on ventral surface near posterior margin of genital double-somite. Copulatory tube leads into cruciform seminal receptacles. Seminal receptacle well developed on each side, with small opening of oviduct into antrum.

Anal somite (Figs. 2B–C) ornamented with pair of sensilla dorsally, with one interrupted and arched row of spines at base of caudal rami ventrally. Anal operculum convex, reaching slightly beyond limit of anal somite and armed with many spinules on its posterior margin. Anal sinus 'S'- (right side) or reversed 'S'- (left side) shaped, with lateral rows of hairs. Caudal rami (Figs. 2B–C) slightly divergent, their length about 2.4 times their width, without inner setule row and protrusion on lateral margin, and with 7 setae each: seta I minute, shortest; setae II and III bare; of apical three setae, inner seta IV tiny, seta V well developed, and outer seta VI plumose; seta VII basally tri-articulated. Small pores present on median ventral margin.

Antennule (Fig. 2A) 7-segmented, segment 1 longest. Armature formula: 1-[1 bare], 2-[9], 3-[6], 4-[1+(1+ae)], 5-[1], 6-[3], 7-[8+acrothek]. Apical acrothek consisting of small aesthetasc fused basally to two slender setae. Segment 1 with spinular rows around anterior margin. Segment 2 with spinular rows around dorsolateral margin. Segment 3 with spinular rows around lateral and posterior margins. Segment 4 with relatively short aesthetasc not reaching middle of 7th segment, and fused basally to seta and set on distinct pedestal.

Antenna (Fig. 3A) comprising coxa with spinules on inner margin, allobasis with 2 long abexopodal setae, free 1-segmented endopod, and 1-segmented exopod. Endopod with 2 spines along anterior margin, and with 2 spines and 3 geniculate setae apically. Exopod small with 2 inner and 2 apical bipinnate setae.

Labrum rhomboidal, with short cutting edge. Anterior margins of both sides with 7 spinules, and row of hairs on median apical margin.

Mandible (Fig. 3B) with knob on outer surface. Gnathobase well developed with several multicuspidate teeth around distal margin and long unipinnate seta at dorsal corner. Rows of fine spinules present on proximal surface. Palp small, 2-segmented; distal segment with 4 smooth apical setae.

Maxillule (Fig. 3C). Praecoxa with arthrite bearing 6 apical spines and 2 setae on anterior surface. Coxa with cylindrical endite bearing spine and seta. Basis with 2 naked setae and curved, pinnate seta. Endopod and exopod incorporated in basis, represented by 2 bare and 2 plumose setae, respectively.

Maxilla (Fig. 3D) comprising syncoxa and allobasis. Anterior surface armed with rows of spinules as shown in Fig. 3D. Syncoxa with 2 endites. Proximal syncoxal endite

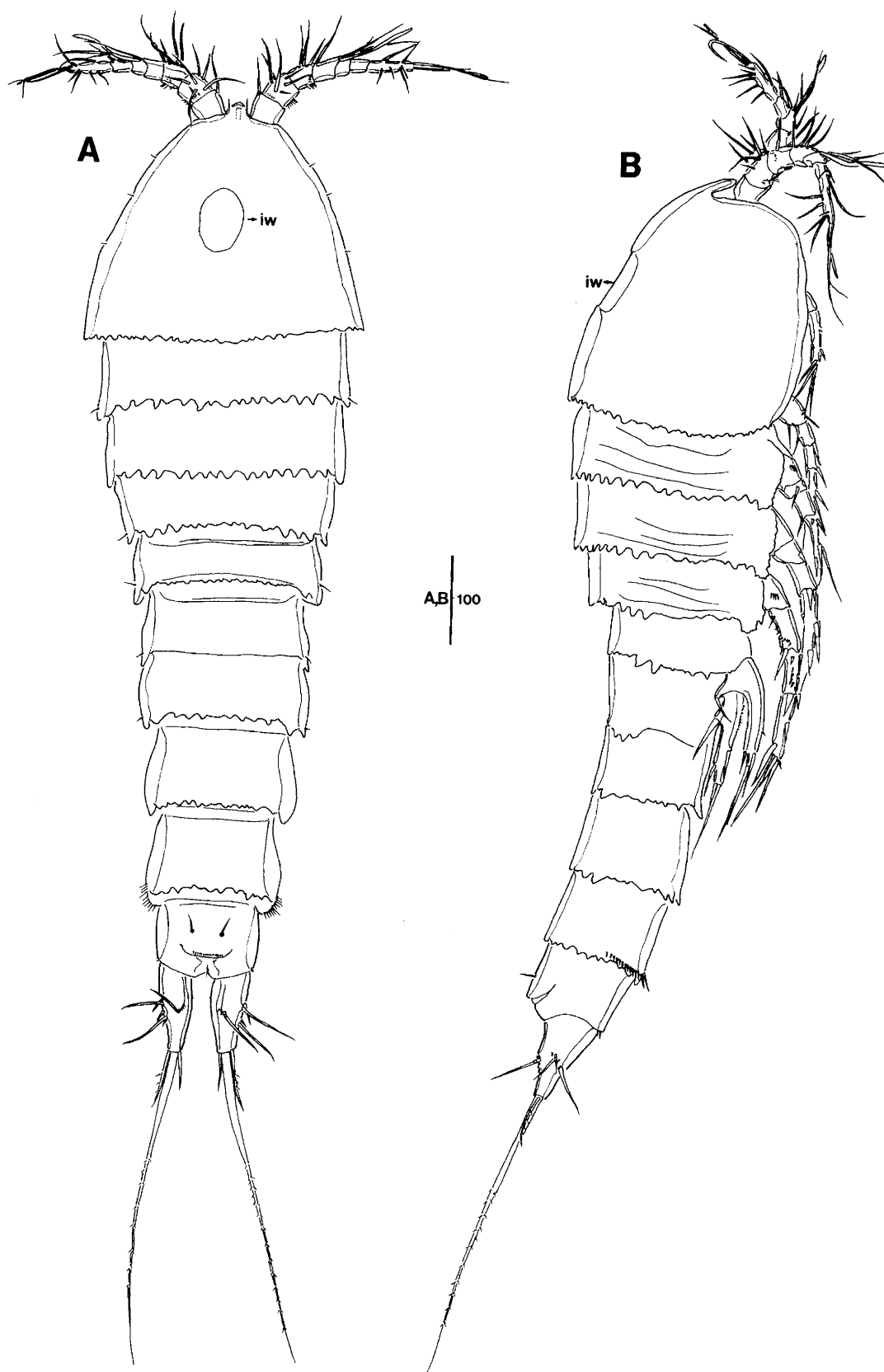


Fig. 1. *Attheyella namkungi* sp. nov., holotype. A–B, female: A, habitus, dorsal view; B, habitus, lateral view.

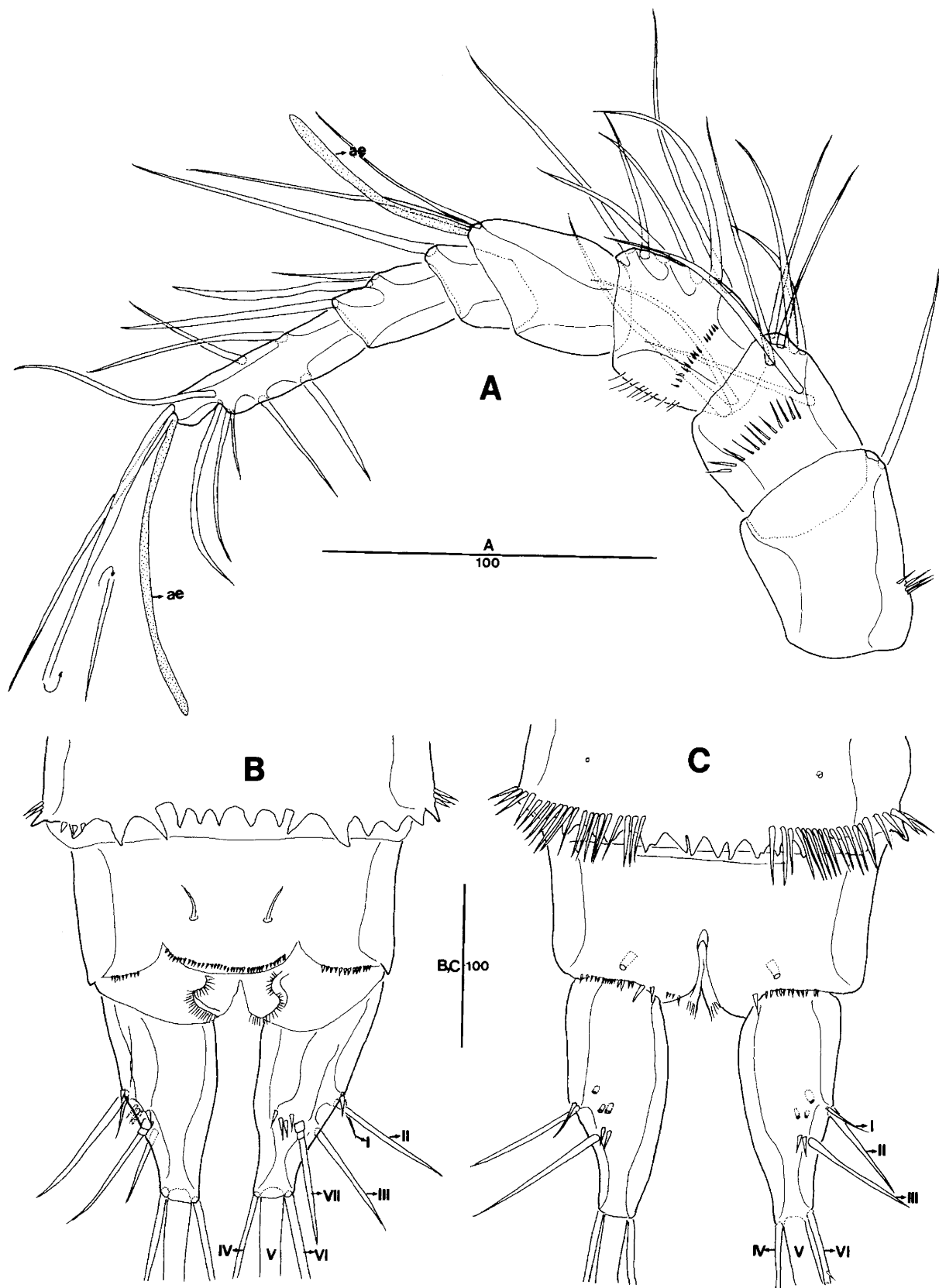


Fig. 2. *Attheyella namkungi* sp. nov., holotype. A–C, female: A, antennule; B, anal somite and caudal rami, dorsal view; C, anal somite and caudal rami, ventral view.

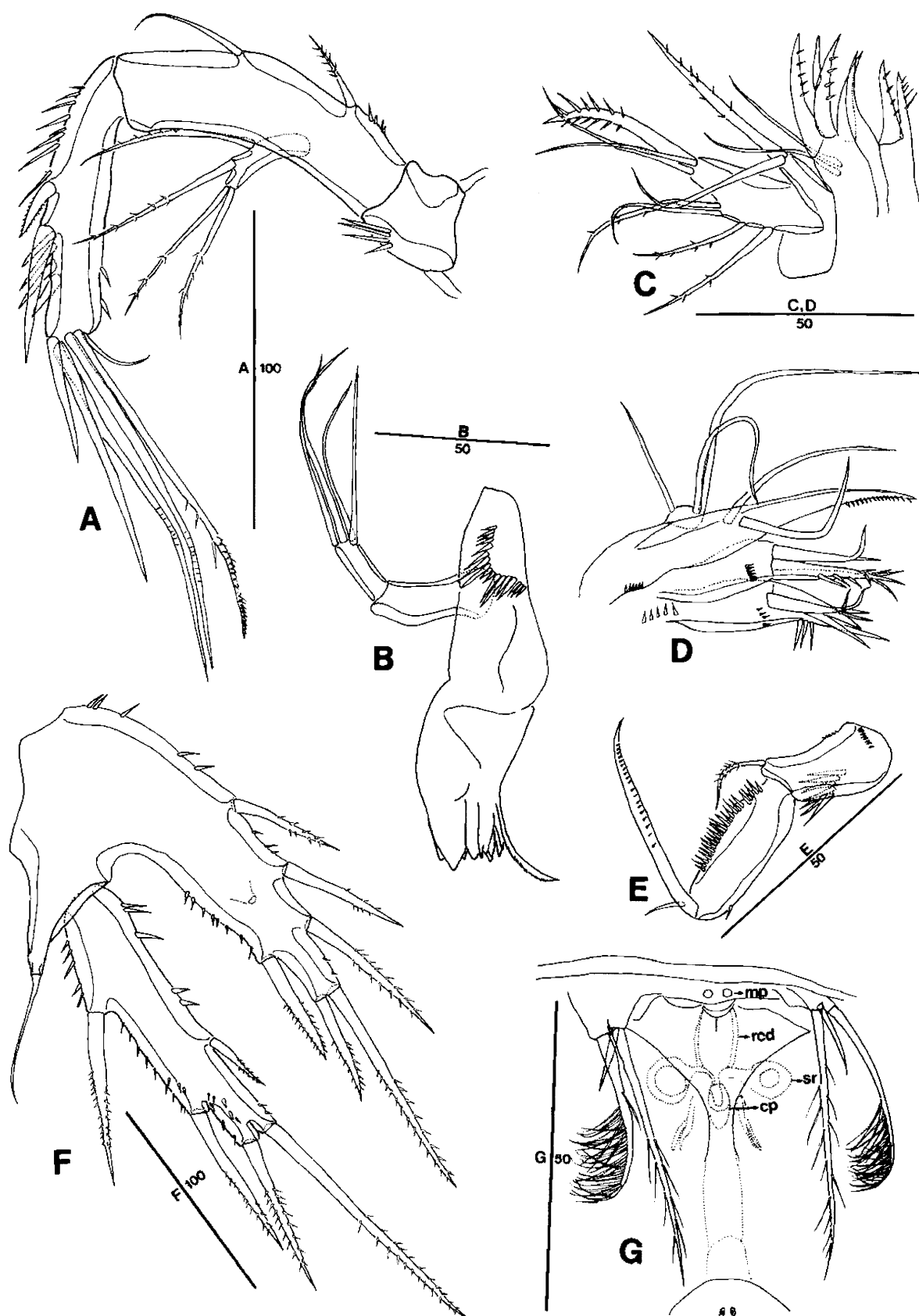


Fig. 3. *Attheyella namkungi* sp. nov., holotype. A–G, female: A, antenna; B, mandible; C, maxillule; D, maxilla; E, maxilliped; F, leg 5; G, genital field.

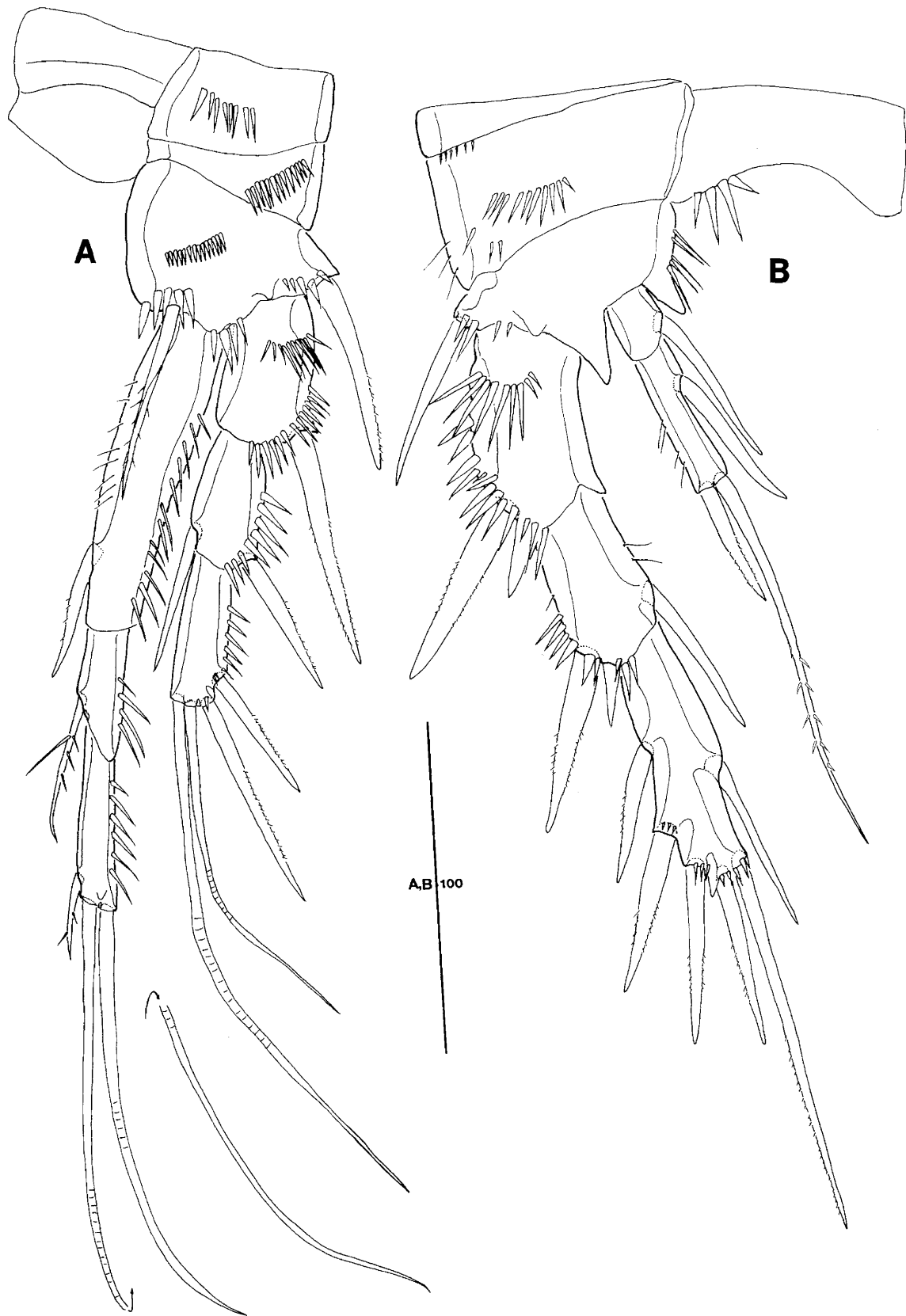


Fig. 4. *Attheyella namkungi* sp. nov., holotype. A–B, female: A, leg 1; B, leg 2.

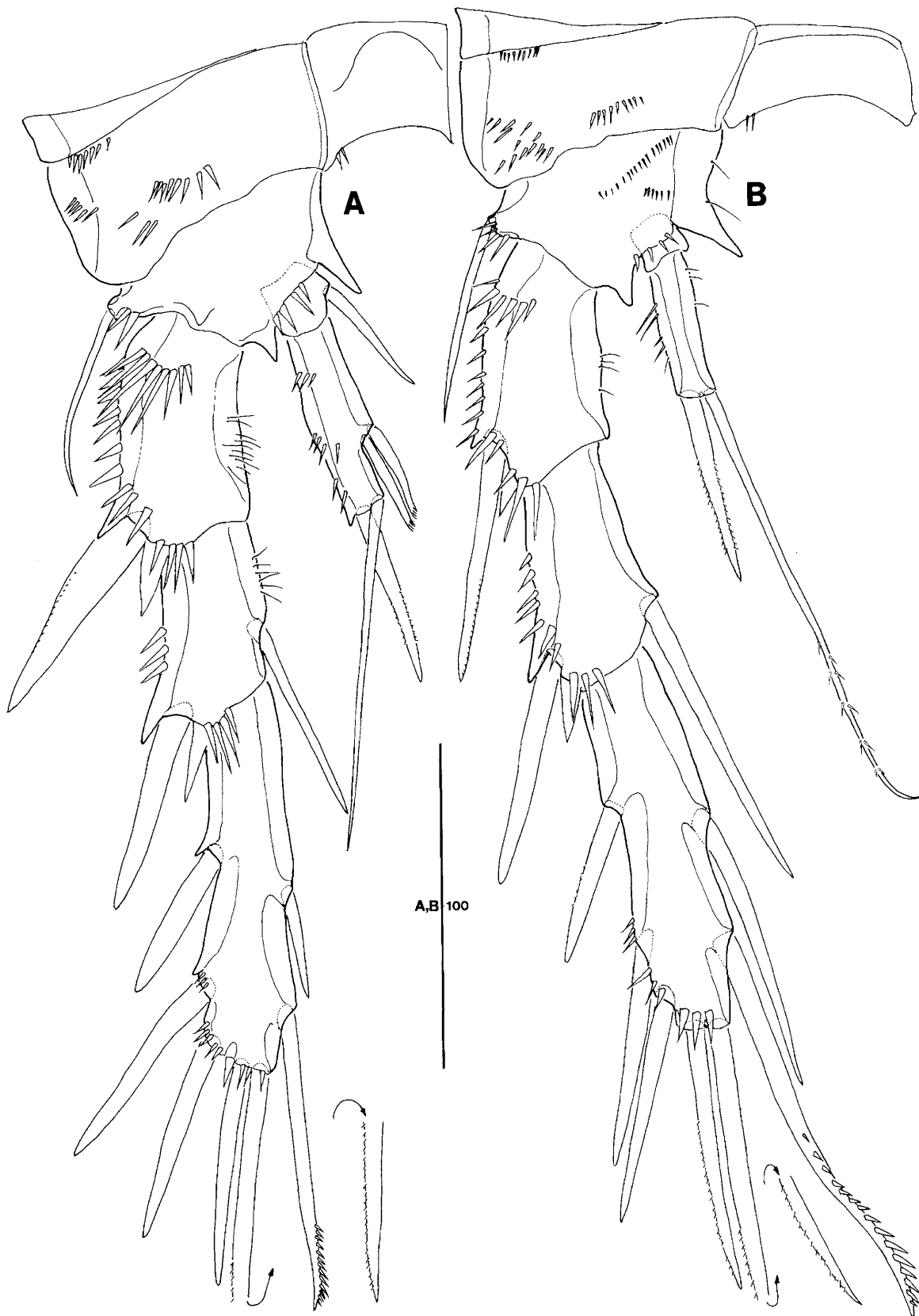


Fig. 5. *Attheyella namkungi* sp. nov., holotype. A–B, female: A, leg 3; B, leg 4.

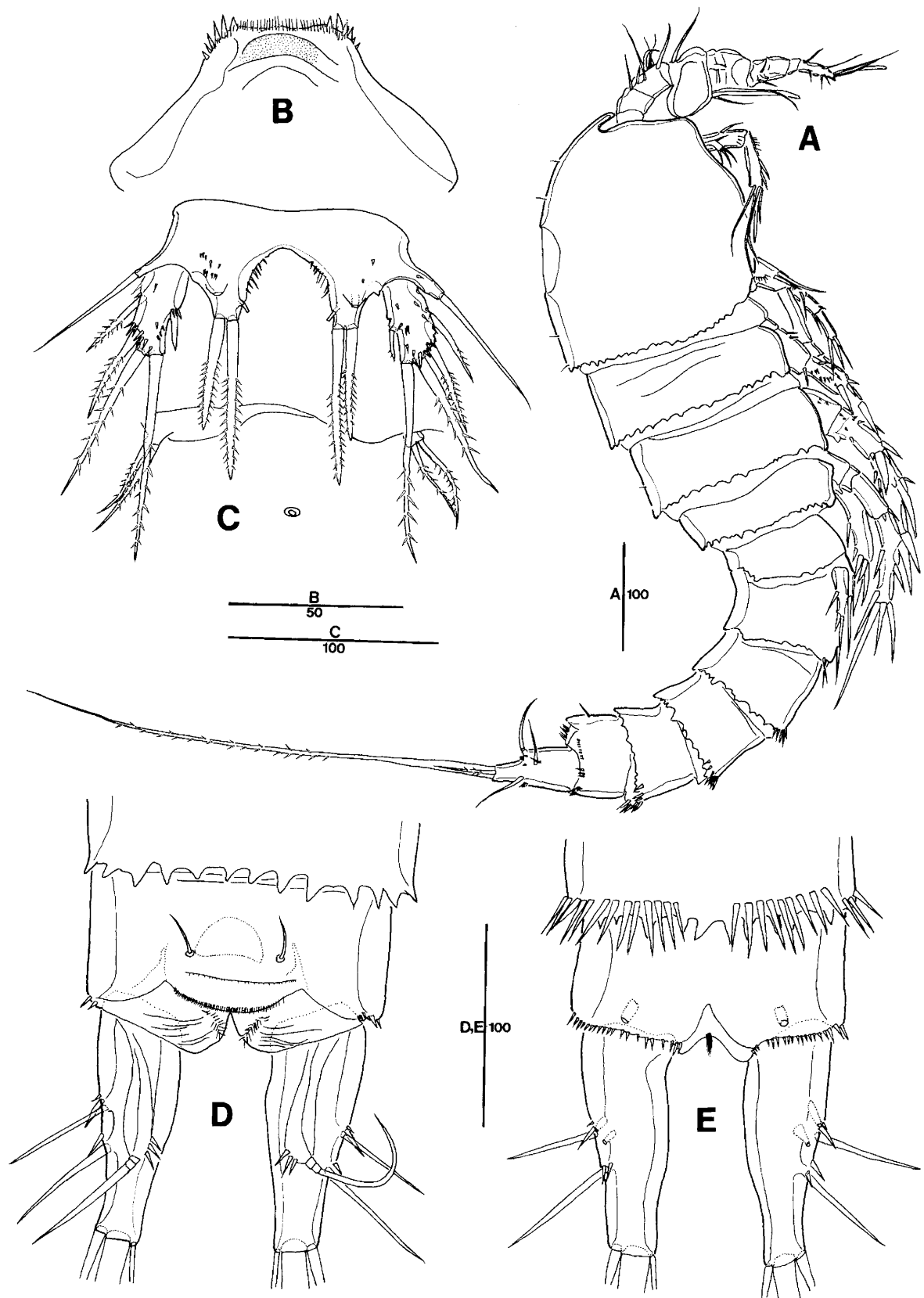


Fig. 6. *Attheyella namkungi* sp. nov., paratype. A–E, male: A, habitus, lateral view; B, labrum; C, leg 5 and leg 6; D, anal somite and caudal rami, dorsal view; E, anal somite and caudal rami, ventral view.

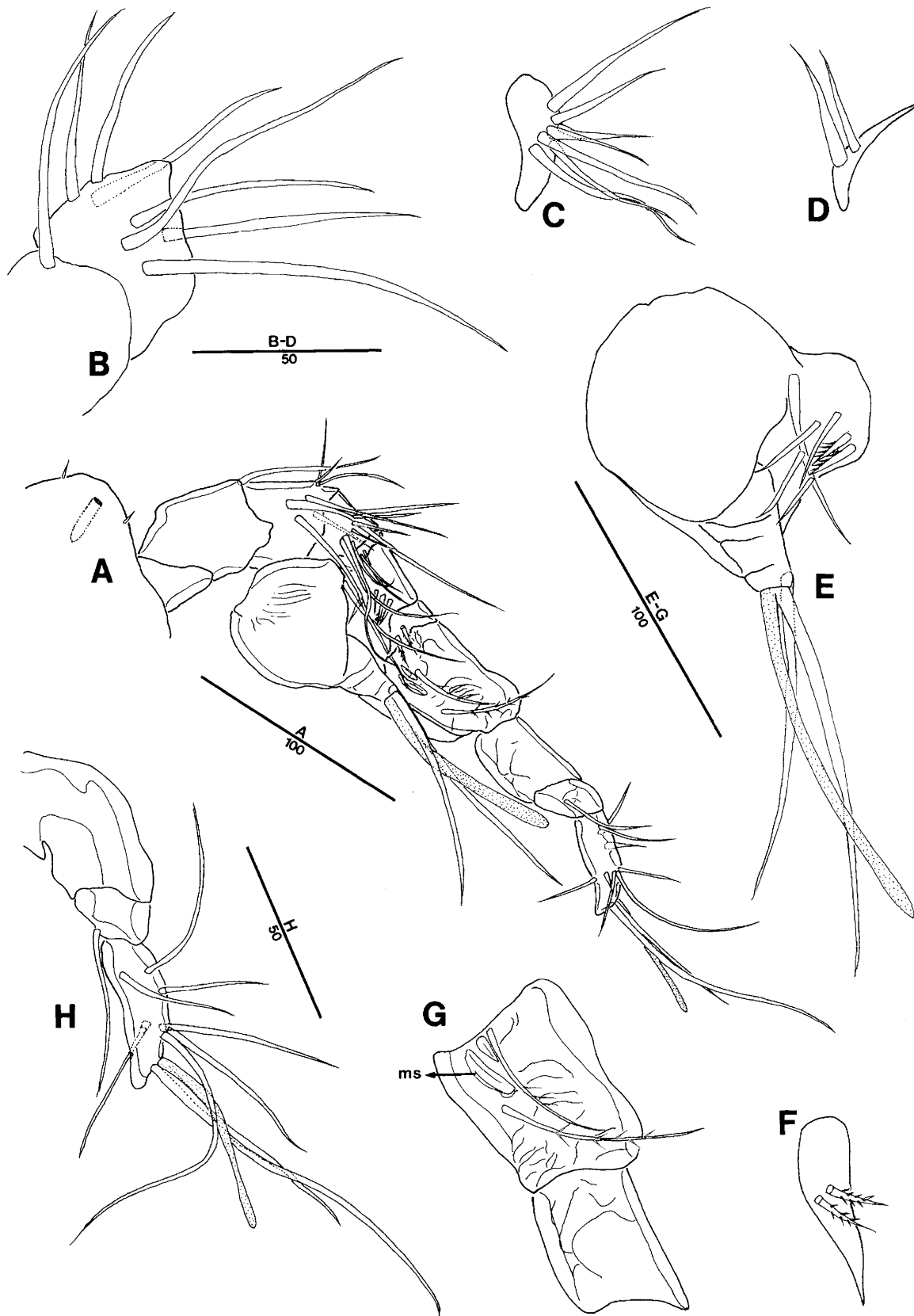


Fig. 7. *Attheyella namkungi* sp. nov., paratype. A–H, male antennule: A, A1 with rostrum; B, segment 2; C, segment 3; D, segment 4; E, segment 5; F, segment 6; G, segments 7 and 8; H, segments 9 and 10.

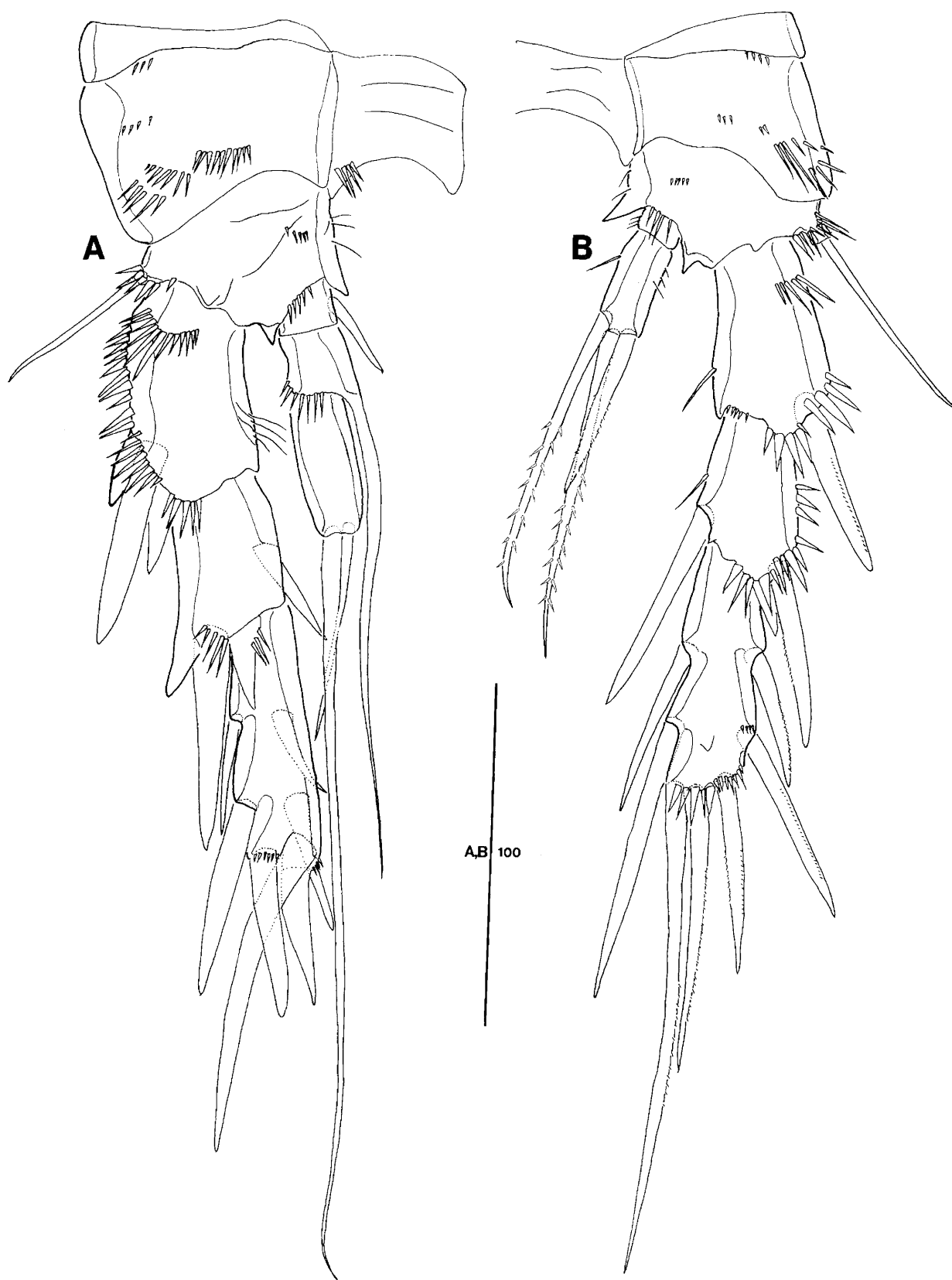


Fig. 8. *Attheyella namkungi* sp. nov., paratype. A–B, male: A, leg 3; B, leg 4.

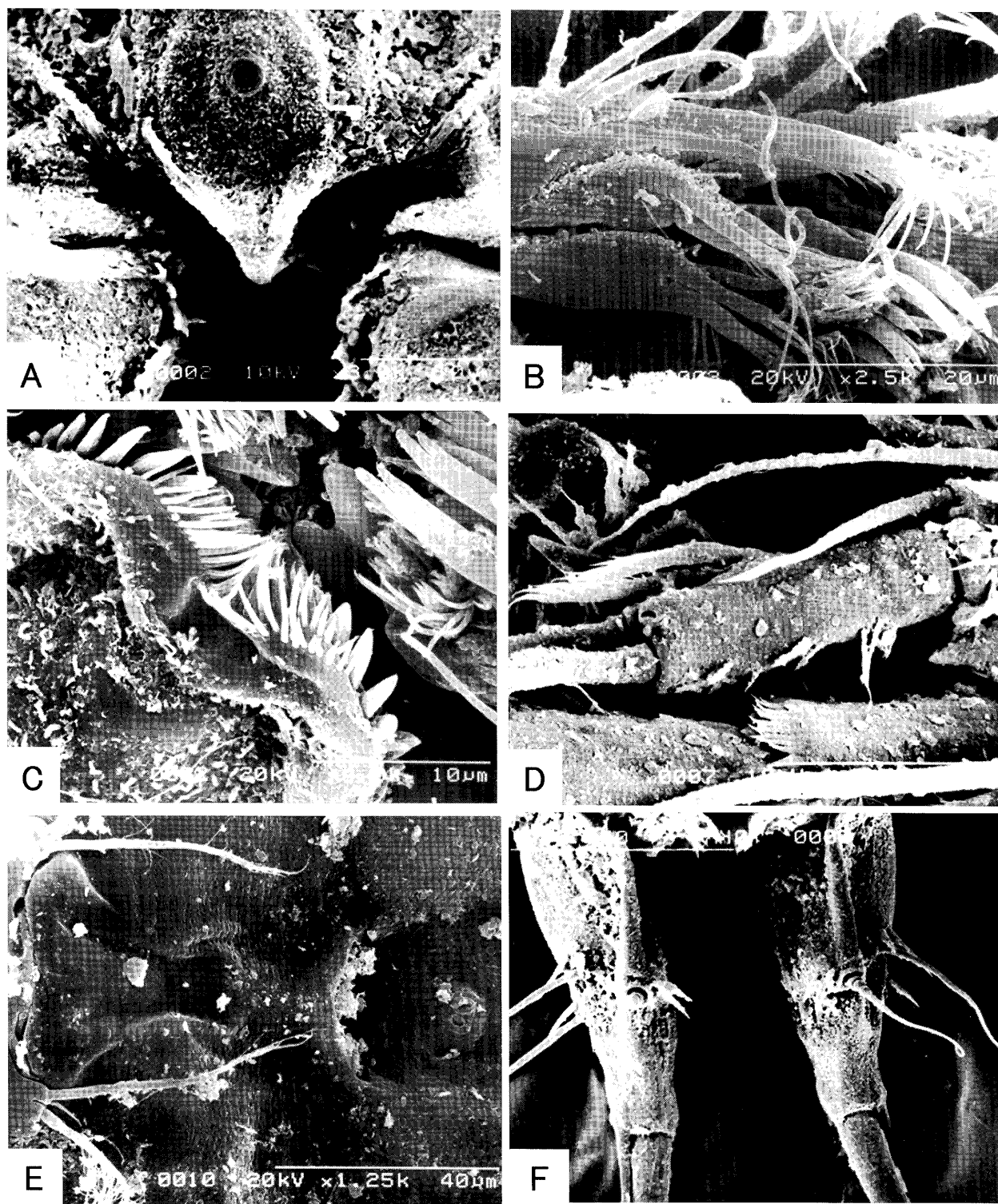


Fig. 9. *Attheyella namkungi* sp. nov., paratype. SEM micrographs, A–F, female. A, rostrum with large pore; B, maxilla with two endites, right part; C, labrum, ventral view; D, leg 3 endopod-2, left part; E, genital field, ventral view; F, caudal rami, dorsal view.

with strong pinnate spine fused to endite, and 2 pinnate spines. Distal syncoxal endite with 3 pinnate spines. Allobasis drawn out into strong, slightly curved claw. Accessory armature consisting of naked seta on anterior surface and naked seta on posterior surface. Endopod 1-segmented,

with 3 naked setae.

Maxilliped (Fig. 3E). Syncoxa with pinnate spine on inner distal corner and row of spinules on outer lateral margin. Basis with one row of spinules on outer lateral margin, and rows of spinules along palmar region. Endopod fused

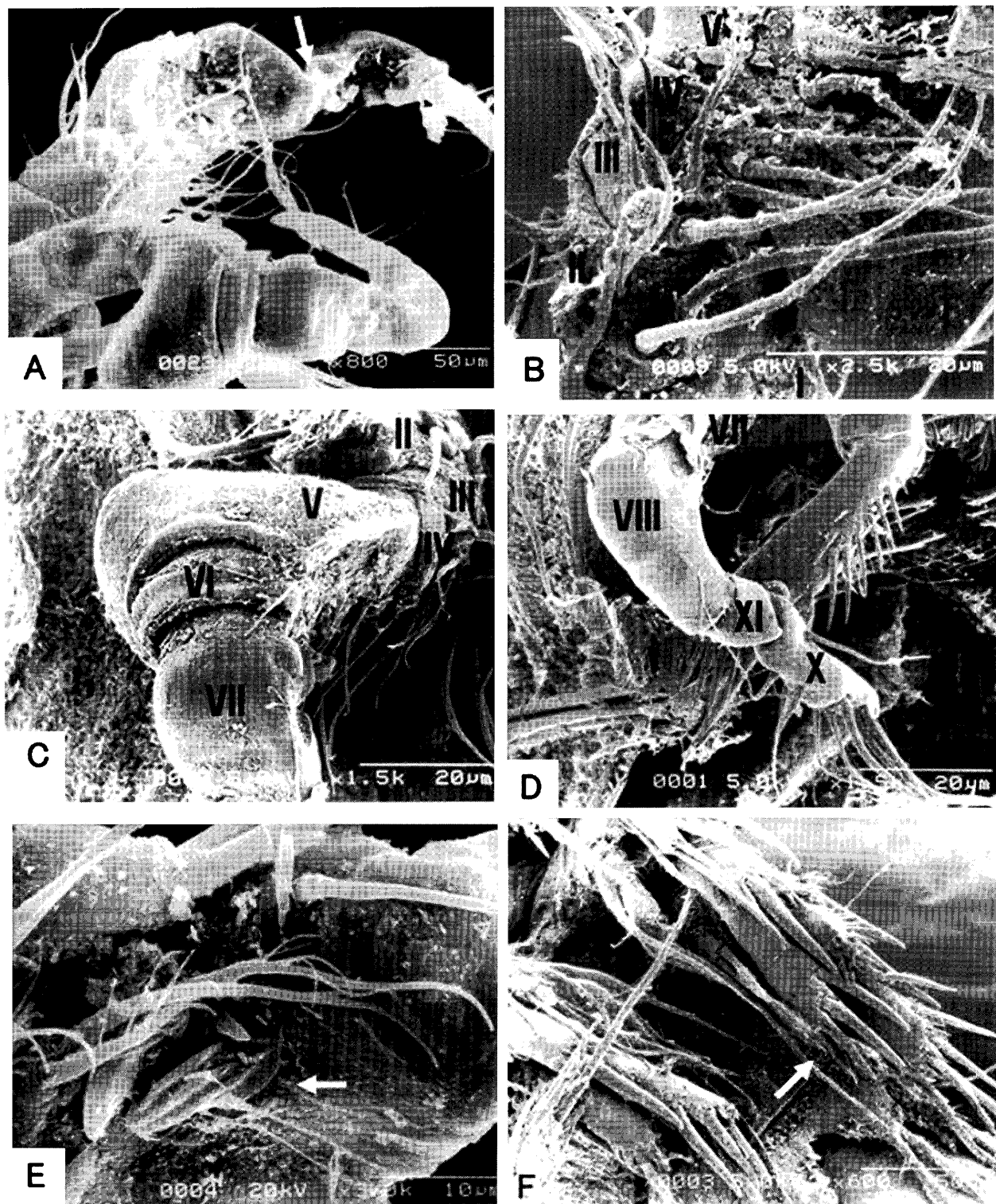


Fig. 10. *Attheyella namkungi* sp. nov., paratype. SEM micrographs, A–F, male. A, antennule, left part, ventral view (geniculation arrowed); B, antennule, segments 1–5, ventral view; C, antennule, segments 2–7, dorsal view; D, antennule, segments 7–10, lateral view; E, antennule, segments 5 and 6 (modified seta arrowed); F, leg 3 endopod-2 without barbed apophysis and 2 apical setae (distal part arrowed).

with a long, pinnate claw. Accessory armature consisting of minute outer seta.

Legs 1–4 (Figs. 4A–B, 5A–B) with wide intercoxal sclerites and well developed praecoxae. Intercoxal sclerites of

legs 1 and 4 without spinules, that of leg 2 with a group of spinules, and that of leg 3 with spinules. Coxae and bases with anterior row of surface spinules as figured. Exopod 3-segmented, endopod 2-segmented except for leg 1. Each

ramus of leg 1 3-segmented.

Leg 1 (Fig. 4A) with large praecoxa, with row of long spinules on anterior surface. Coxa with row of spinules on anterior surface. Basis with strong, bipinnate spine and spinules along inner margin, and with stout pinnate spine and spinules along outer margin. Endopod 1.5 times as long as exopod. Enp-1 about 4 times as long as wide and 2.4 times as long as enp-2, with rows of spinules along outer and inner margin. Exopod reaching middle of enp-2. Exp-2 shortest, and exp-1 subequal to exp-3 in length.

Legs 2–4 (Figs. 4B, 5A–B). Coxae and bases with spinular rows along outer margin. Outer margin of basis with stout spine (leg 2) or naked seta (legs 3–4). All segments with pattern of spinules as figured.

Leg 2 enp-2 twice as long as enp-1. Endopod reaching proximal area of exp-2. Enp-2 with row of spinules along outer margin. Exp-2 with row of setules along inner margin.

Leg 3 enp-2 3 times as long as enp-1. Endopod reaching proximal area of exp-2. Rows of spinules along anterior lateral surface of enp-2. Two pinnate inner setae of enp-2 located close to each other (Figs. 5A, 9C). Exp-2 shortest and exp-3 1.6 times as long as exp-1. Exp-1 and exp-2 with row of setules along inner margin.

Leg 4 enp-2 twice as long as enp-1. Endopod not reaching distal margin of exp-1. Exp-1 subequal to exp-2. Exp-3 largest and 1.6 times as long as exp-1.

Spine and setal formulae are as follows:

	Exopod	Endopod
Leg 1	0.1.022	1.1.120
Leg 2	0.1.123	1.120
Leg 3	0.1.223	1.220
Leg 4	0.1.223	0.020

Leg 5 (Fig. 3F). Baseoendopod forming short, outer setophore bearing basal seta and rows of spinules along inner and outer margins. Endopodal lobe long, and not reaching distal margin of exopod, with 3 pinnate inner setae laterally, 2 pinnate setae apically, and pinnate outer seta laterally. A secretory pore is present in middle of endopod. Row of short spinules along outer margin. Exopod elongate, slightly tapering distally, with short inner, 2 apical, and 2 outer bipinnate setae of different lengths. Rows of spinules along inner and outer margins.

Leg 6 (Fig. 3G) with small protuberance bearing pinnate spine, slender pinnate seta, and small seta.

Male (Paratypes)

More slender than female. Body length=845–855 μm ($n=5$). Largest width=250 μm , measured at posterior margin of cephalic shield. Urosome distinctly narrower than prosome and comprising 5 pedigerous somites and 5 free abdominal somites. First abdominal somite about 1.5 times as broad as long. Anal sinus smooth, with lateral rows of hairs. Caudal rami (Figs. 6D–E) about 2.8 times as long as

wide.

Antennule (Figs. 7A–H) 10-segmented. Subchirocer with geniculation between segments 5 and 6, and between segments 7 and 8. Segments 4 and 6 represented by small sclerites along anterior margin. Segment 5 largest and swollen. Segment 10 triangular. Armature formula: 1-[1 bare], 2-[7 bare], 3-[7 bare], 4-[2 bare], 5-[2 pinnate+6 bare+(1+1ae)], 6-[2 pinnate], 7-[1 pinnate+1 bare], 8-[0], 9-[1 bare], 10-[7 bare+acrothek]. Aesthetasc on segment 5 short and not reaching distal margin of segment 9. Apical acrothek consisting of minute aesthetasc and 2 naked setae.

Antenna, labrum (Fig. 6B), mandible, maxillule, maxilla, maxilliped, leg 1, and exopods of legs 2–4 same as in female.

Leg 3 endopod (Fig. 8A) 3-segmented and modified. Endopod reaching middle of exp-2. Enp-1 shortest, with inner seta. Enp-2 with long spiniform process homologous with one of two inner setae of enp-2 in ♀. Enp-3 longest, with 2 apical setae; inner seta very long and exceeding length of outer seta of leg 5. Setae and spines on exopod modified, shorter and stouter than those in ♀ (Fig. 5A).

Leg 4 (Fig. 8B) endopod 2-segmented. Endopod not reaching middle of exp-1. Enp-1 short, without seta. Enp-2 with inner and 2 apical setae; outer apical seta shorter than inner. Enp-2 twice as long as wide. Setae and spines on exopod modified, shorter and stouter than those in ♀ (Fig. 8B).

Leg 5 (Fig. 6C) fused medially and defined at base. Baseoendopod with short setophore bearing outer basal seta, and with well-developed trapezoid endopodal lobe having tube pore on inner margin, large pore on anterior surface, and 2 apical setae; inner one longer than outer, and with several spinules along inner margin and on anterior surface. Exopod subrectangular, about 1.6 times as long as broad, and with short inner, 2 apical, and 2 outer setae; several spinules on anterior surface.

Leg 6 (Fig. 6C) asymmetrical, represented on both sides by small plate (fused to ventral wall of supporting somite along right side, articulating at base and covering gonopore along left side). Outer distal corner extended into cylindrical process bearing 2 pinnate setae.

DISCUSSION

The new species is placed in *Attheyella* on account of having a 3-segmented endopod of leg 1, a 2-segmented endopod of legs 2–4, three outer spines on exp-3 of legs 2–4, five setae on the exopod and six setae on the baseoendopod of leg 5, and three setae on enp-2 of leg 2.

Attheyella namkungi sp. nov. appears to be most closely related to *A. coreana* Miura, 1969, a cave dwelling species known from Daeya cave and three other caves in Korea. The close relationship between the two species is indicated by the following combination of shared character states: 1) 7-segmented female antennule, 2) identical setal formula of legs 1–5, 3) elongated leg 5 exopod and endo-

pod, and 4) 2-segmented mandibular palp with only four smooth apical setae. Although the armature formula of legs 1–5 in *A. namkungi* is identical to that of *A. coreana*, both species can be easily distinguished on the basis of caudal ramus shape (somewhat cylindrical in *A. namkungi*, ovoid in *A. coreana*); spinular rows on inner margin of caudal ramus (absent in *A. namkungi*, present in *A. coreana*); inner lateral spine of female P5 exopod (more proximally located in *A. namkungi*, more distally in *A. coreana*); setal number of P6 (three in *A. namkungi*, two in *A. coreana*); and the two inner lateral setae on P3 enp-2 (close together in *A. namkungi*, somewhat separate in *A. coreana*). Although *A. namkungi* is clearly distinguishable from the originally described *Attheyella coreana* Miura, 1969, taxonomic problems remain with the latter due to incomplete descriptions and unconfirmed reports from several localities.

Ishida and Ito (1991) claimed the presence of sexual dimorphic caudal rami in *A. coreana* from South Primorye, Russia. They also argued that *A. coreana*, identified as *A. coiffaiti* by Ishida (1990, 1995), is distributed on Kyushu and Tsushima Islands, Japan. *A. coreana sensu* Ishida and Ito (1991), with the sexually dimorphic caudal rami, differs from Miura's (1969) original description in the long apical setae on enp-3 of leg 1, the short enp-1 of leg 1 only reaching the proximal margin of exp-3 of leg 1, the closely located two inner setae on enp-2 of leg 3 in females, and the apophysis of enp-2 of leg 3 far exceeding the inner apical seta on enp-3 of leg 3 in males. However Miura (1969) clearly described that the furcal rami of *A. coreana* of males are similar to those of females. Considering the preceding combination of characters and its geographical distribution, *A. coreana sensu* Ishida and Ito (1991) seems to be a distinct species from *A. coreana* Miura, 1969, and further study is needed to confirm its taxonomical status.

Chang (1993) also claimed sexually dimorphic caudal rami in *Attheyella coreana* from various localities in Korea, without providing illustrated descriptions for the species. Chang and Lee (2003) confirmed that *A. coreana* has sexually dimorphic caudal rami, and they ignored Miura (1969)'s original description of the species without a clear explanation why. There are certainly two lineages within *A. coreana*, distinguishable by presence or absence of sexual dimorphism in the caudal rami. *A. namkungi* shows only a slight difference in caudal rami between females and males, as in the original description of *A. coreana* by Miura (1969). The male caudal ramus is slightly longer than that of the female (length:width ratio is 2.8 in males, 2.4 in females). The shape of the caudal ramus is the same in both sexes. The weak sexual dimorphism in caudal rami of *A. namkungi*, and in *A. coreana* mentioned by Miura (1969) and Ishida (1995), could be a synapomorphic character for the cave dwellers in the region. An additional example of non-sexually dimorphic caudal rami can be found in another cave dweller, *A. coiffaiti* from caves in Japan (Ishida, 1995).

The mandibular palp of *Attheyella namkungi* is two-segmented and armed with four naked apical setae on the sec-

ond segment (Fig. 3B). The number and location of these setae are unique among the reported *Attheyella* species. Unfortunately, previous descriptions ignored mouthpart structures of *Attheyella*. However, several reports treated mandibular architecture: only one segmented, with three apical setae in *A. (Canthosella) mervini* (Janetzky *et al.* 1996); two-segmented (setal formula, 0:0.2) in *A. coiffaiti* (Chappuis, 1958); two-segmented (2:0.4) in *A. (Mrazekiella) osmana* (Por, 1983); two-segmented (1:0.5) in *A. (Attheyella) jureiae* (Por and Hadel, 1986); two-segmented (1:0.3) in *A. (Mrazekiella) spinipes* (Reid, 1987); two-segmented (1.03) in *A. (Attheyella) paucisetosa* (Chang and Kim, 1992); two-segmented (1.03) in *A. (Mrazekiella) tetraspinosa* (Chang, 1993); and two-segmented (0:1.4) in *A. (Mrazekiella) wulmeri* (Karanovic, 1999). Considering that the mandibular palp exhibits several patterns even within a subgenus, the current subgenera of *Attheyella* based on characters mainly from the swimming legs certainly need to be redefined after confirming the mouthpart structures, including the mandibular palp.

A key to the genus *Attheyella* from Korea (amended from Chang and Lee, 2003)

1. Antenna exp. 1-segmented, with 4 setae. 2
 - Antenna 2-segmented, with 3 setae *Attheyella crassa* (Sars, 1862)
2. Antennule 8-segmented and anal operculum with triangular hyaline *Attheyella orientalis* Chappuis, 1929
 - Antennule 7-segmented and anal operculum convex 3
3. Leg 1 endopod-1 longer than exopod 4
 - Leg 1 endopod-1 shorter than exopod 5
4. Leg 5 baseoendopod bearing 6 setae and male leg 2 endopod-2 with 5 (320) setae *Attheyella byblis* Chang & Kim, 1992
 - Leg 5 baseoendopod bearing 4 setae and male leg 2 endopod-2 with 4 (220) setae *Attheyella tetraspinosa* Chang, 1993
5. Leg 3 endopod-2 bearing 4 (220) setae and leg 4 endopod-1 without seta 6
 - Leg 3 endopod-2 bearing 5 (221) setae and leg 4 endopod-1 with seta *Attheyella paucisetosa* Chang & Kim, 1992
6. Male leg 3 apophysis shorter than inner apical seta on enp-3, and caudal rami distinctly sexually dimorphic 7
 - Male leg 3 apophysis longer than inner apical seta on enp-3, and caudal rami slightly sexually dimorphic *Attheyella namkungi* sp. nov.
7. Leg 2 endopod-2 bearing 2 (020) setae and leg 4 endopod-2 with 3 apical setae *Attheyella nakaii* (Brehm, 1927)
 - Leg 2 endopod-2 bearing 3 (120) setae and leg 4 endopod-2 with 2 apical setae *Attheyella coreana* Miura, 1969

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